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ABSTRACT

Two studies were reported which attempted to estimate the stability and construct validity of human salivary response as a measure of individual differences (IDs) in physiological arousal. Twenty-second base line estimates and 20-second response levels to four drops of lemon juice were measured, with the former value being removed from the latter to form the salivary score for a given subject. The first study obtained a test-retest correlation over 24 hours for the net salivation score of 0.78 ($N = 25$; $p<.001$). The second study involved the measurement of the threshold of fusion of paired light flashes [two-flash threshold (TFT)], a previously validated index of arousal, as well as salivation. The correlation between net salivation and TFT on 25 subjects was -.57 ($p<.01$). It was concluded that the salivary measure has demonstrated promising psychometric properties for use in ID research. (Author)

Working Paper No. 51

The Reliability and Validity of Salivation as a Measure of Individual Differences in Intrinsic Arousal

Report from the Project on Motivation and Individual Differences in Learning and Retention

Wisconsin Research and Development
CENTER FOR COGNITIVE LEARNING

THE UNIVERSITY OF WISCONSIN
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THE RELIABILITY AND VALIDITY OF SALIVATION AS A MEASURE OF INDIVIDUAL DIFFERENCES IN INTRINSIC AROUSAL

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Report from the Project on Motivation and
Individual Differences in Learning and Retention
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STATEMENT OF FOCUS

The Wisconsin Research and Development Center for Cognitive Learning focuses on contributing to a better understanding of cognitive learning by children and youth and to the improvement of related educational practices. The strategy for research and development is comprehensive. It includes basic research to generate new knowledge about the conditions and processes of learning and about the processes of instruction, and the subsequent development of research-based instructional materials, many of which are designed for use by teachers and others for use by students. These materials are tested and refined in school settings. Throughout these operations behavioral scientists, curriculum experts, academic scholars, and school people interact, insuring that the results of Center activities are based soundly on knowledge of subject matter and cognitive learning and that they are applied to the improvement of educational practice.

This working paper is from the Motivation and Individual Differences in Learning and Retention Project from Program 1. General objectives of the Program are to generate new knowledge about concept learning and cognitive skills, to synthesize existing knowledge, and to develop educational materials suggested by the prior activities. Contributing to these Program objectives, the Learning and Memory Project has the long-term goal of developing a theory of individual differences and motivation. The intermediate objective is to generate new knowledge of the learning and memory processes, particularly their developmental relationship to individual differences and to motivation.

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INTRODUCTION

A number of recent studies have investigated the relationship between arousal and retention in which the arousal effects induced by the stimulus material were monitored during learning by measures of skin resistance (Berry, 1962; Lovejoy & Farley, 1969; Kleinsmith & Kaplan, 1963, 1964; Kleinsmith, Kaplan, & Tarte, 1963; Walker & Tarte, 1963; Maltzman, Kantor, & Langdon, 1966; Levonian, 1968). Changes in levels of skin resistance coincident with a particular stimulus were usually presumed to be induced by that stimulus. These studies were thus primarily interested in the relationship between stimulus-related arousal and recall of verbal material over varying retention intervals.

It has been pointed out that these experiments ignored the role of individual differences in intrinsic levels of subject (S) arousal (Farley & Gilbert, 1968; Osborne & Farley, 1970). It seems reasonable to assume that the S's level of arousal during learning is the product of at least these two sources of arousal. In an attempt to assess the value of this hypothesis Farley and Gilbert (1968) reported a study similar to that of Kleinsmith and Kaplan (1964) except that Ss (children) were assigned to high- and low-arousal categories on the basis of salivary output to four drops of

lemon juice (Corcoran, 1964; Eysenck & Eysenck, 1967). The results indicated a significant interaction between level of arousal measured in this fashion and recall over short- and long-term retention intervals such that high-arousal Ss demonstrated inferior short-term retention but superior long-term retention relative to low-arousal Ss, who demonstrated good short-term retention but marked forgetting over the long-term interval. Osborne and Farley (1970) obtained similar results using college students as Ss.

Some justification for the use of salivation as an index of arousal can be found in Sternbach (1966) who has argued that salivation is an index of the balance between the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). More saliva indicates apparent PNS dominance; less saliva indicates apparent SNS dominance. Sternbach maintains that the PNS/SNS balance may be an index of arousal. Consequently it can be hypothesized that the effector output of a highly aroused organism is greater than that of a lesser aroused organism when both are subject to the same stimulation, if in fact, as Bremer (1954) suggests, the neurophysiological correlate of high levels of activation is a state of high cortical facilitation.

In the extent to which salivation is to be used as an index of individual differences (IDs) in arousal, then a primary prerequisite must be a demonstrated reliability of measurement.

In regard to retest reliability estimates, Corcoran (1964) did not specifically report retest correlations for the three measures involved in his procedure except to say that they were very high (in excess of 0.90 with $p < .01$); however, only 11 Ss were employed, and the duration of the retest interval was not reported. Eysenck and Eysenck (1967) obtained the following test-retest correlations on 24 Ss with a 24-hour retest interval: for basal salivation (sampled over 20 seconds), $r = 0.33$; for gross salivation (salivation to lemon juice over a 20-second period), $r = 0.71$; for net salivation (gross salivation minus basal salivation), $r = 0.60$. In light of the generally low reliability estimates obtained by Eysenck and Eysenck, and the small N and insufficient procedural information in the Corcoran report, it was felt that a study specifically designed to obtain stability estimates was required.

In addition to reliability, the usefulness of salivation as a measure of IDs in arousal will depend on demonstrated validity. One approach to estimates of validity is through construct validation, which can be achieved through the correlation of the measure under investigation with another measure of the presumed same theoretical construct. One task that has received considerable recent attention as a putative measure of IDs in cortical arousal is the two-flash threshold (TFT) (Hume & Claridge, 1965; Maley, 1967; Rose, 1966; Venables, 1963;

Venables & Warwick-Evans, 1967) which is defined as the inter-flash interval at which pairs of flashes appear to fuse to produce the perception of a single flash. The use of this measure was suggested by the work of Lindsley (1957) in which stimulation of the reticular formation of cats was shown to improve optic cortical resolution. The best evidence with human Ss for a relationship between TFT and cortical arousal has bee the work of Venables and Warwick-Evans (1967) in which a significant correlation of .56 between TFT and amplititude of the EEG alpha rhythm was obtained, and by Kopell, Noble, and Silverman (1965) who demonstrated that thiamylal significantly raised, and methamphetamine significantly lowered, TFT.

In view of the encouraging results of learning experiments using salivation as an index of arousal (Farley & Gilbert, 1968; Osborne & Farley, 1970) and the questionable reliability of the procedure, the present study was undertaken in order to (a) obtain an estimate of the temporal stability of salivary response to four drops of lemon juice and (b) estimate its validity in terms of another independent measure of arousal (TFT).

II

EXPERIMENT 1: RELIABILITY

METHOD

Subjects

The Ss were 18 female and 7 male volunteers from an undergraduate course in learning and human abilities at the University of Wisconsin.

Apparatus

Fresh lemon juice was squeezed into a glass beaker after having been strained through a fine wire gauze. Standard cotton dental swabs were used in conjunction with 50 (16 x 150 mm.) test tubes and stoppers (size "0") to obtain from each S a measure of salivary output to lemon juice which was placed on the tongue by means of a 1 c.c. glass syringe. Stainless steel forceps were used for the deposition and removal of the swabs. The forceps were sterilized for each S in an American Sundries Co. Renewal Electric Sterilizer Model No. 5. The weighing of swabs and test tubes was done with a Right-a-Weigh electronic balance. A stopwatch was used for timing while a 9 inch x 6 inch mirror was available for rehearsal of mouth movements. Forceps were removed from the sterilizer by means of tongs and dried with clean tissues. The equipment was arrayed on a covered aluminum tray.

Procedure

A measure of salivary response to lemon juice was taken from each S by means of the absorbent technique (Razran, 1935). Standard cotton dental swabs were used throughout while equipment coming into contact with the S's mouth was sterilized. Each S was told that this measure was one of a series of physiological measures being taken in a study of individual differences.

Basal salivation was first measured by placing a cotton dental swab upon the sublingual salivary gland by means of forceps. In order to do this the S was told to touch roof of his mouth with the tip of his tongue about halfway back. The S was then told to gently lower his tongue onto the pad without attempting to manipulate it. The S was also instructed that after an interval of 20 seconds he would be told to raise his tongue in the same manner for the removal of the swab. After its removal the moistened swab was placed in a sealed test tube to be weighed. Before measurement began the experimenter (E) demonstrated the two basic mouth movements and provided a mirror for rehearsal by the S.

In measuring gross salivation to four drops of lemon juice the S was told that the initial procedure would be repeated but with modifications. This time, once the swab was in place, the S was told to hollow out his tongue for the reception of four drops of harmless fluid which were to be kept on the tongue for 20 seconds. At the end of this interval the S was told to

simultaneously raise his tongue (for removal of the swab) and swallow the fluid. This measurement began 2 minutes after the beginning of the measurement of basal salivation.

The four drops of lemon juice (mean weight of .176 grams) were delivered to the tongue by means of a 1 c.c. glass syringe. In order to be sure of stimulating the sour taste receptors, the juice was dropped onto the lateral margins of the tongue allowing it to run towards the center. At the end of 20 seconds the moistened swab was removed to be placed in a sealed test tube which had been previously weighed while containing the same swab in a dry state. The test tube and swab were weighed a second time, the difference between wet and dry weights constituting the amount of salivation to lemon juice. This procedure was identical to that employed in obtaining the previous estimate of basal salivation, except for the use of lemon juice. This operation was carried out with the utmost speed and precision. The S was seated so that the equipment tray was out of view. Care was taken not to use the words "lemon" or "juice" or let the S have a close look at the syringe. Every effort was made to minimize distractions in the room in order to avoid spatial inhibition (Eysenck & Yap, 1944).

The difference between basal and gross salivary resp constituted the net salivary output for each S. The entire procedure was repeated 24 hours later under as nearly identical conditions as possible for each S, without the S being informed that the retest would take place.

RESULTS AND DISCUSSION

Product-moment correlation coefficients calculated for test-retest scores yielded the following results: for basal salivation, $r = 0.81$; for gross salization to lemon juice, $r = 0.78$; for net salivation to lemon juice, $r = 0.78$. These values were all significant at the $p < .001$ level.

The correlations obtained demonstrate that the procedure used in this experiment had good temporal stability. This is somewhat surprising in view of the many opportunities for the entry of unwanted variance into a procedure such as the absorbent technique. However, the results are consistent with those of Corcoran (1964), who failed however to state the time between test and retest, and to a lesser extent Eysenck and Eysenck (1967) who used a test-retest interval of 24 hours.

Corcoran did not specifically report retest correlations for the three measures involved, but simply noted that they all exceeded 0.9. Using 24 Ss Eysenck and Eysenck obtained test-retest correlations ranging from .33 to .71 and attempted to explain the fact that these values were somewhat lower than Corcoran's in terms of Ss being conditioned to ". . . think of lemons and imagine the administration of lemon juice even on the first trial of the second administration; this might be the case particularly with introverted Ss who have been reported to form conditioned responses more easily" (Eysenck & Eysenck, 1967, p. 150). This explanation loses some of its cogency when the results of the present experiment are added to

those of Corcoran. Although not as high as those of Corcoran, the correlations in the present experiment are considerably higher than those of Eysenck and Eysenck. It might be added that the Ss used were relatively sophisticated rather than naive and might well have been expected to develop response sets after the initial measurement which would have reduced reliability. If this were so, it did not greatly attenuate the stability estimates obtained. An explanation of Eysenck and Eysenck's results may be simply a possible failure to accurately duplicate the original procedure on retest. Neither Corcoran nor Eysenck and Eysenck stated the time intervening between the basal measure and the later measured response to lemon juice. If one measure immediately followed the other, then it can be postulated that the time necessary for basal salivation to reach its usual base level following measurement may not have elapsed for some individuals. This rate of return to baseline may be an ID which is not proportional to differences in basal salivation. For this reason an interval of 2 minutes was used in the present experiment, on the assumption that this would allow sufficient time for return to baseline in most Ss.

The results of this study add weight to the implication of the experiment of Corcoran; namely, that measuring salivation to lemon juice by means of the absorbent technique is surprisingly reliable in view of the many opportunities for variance within the individual and the measurement procedure.

III

EXPERIMENT 2: VALIDITY

METHOD

Subjects

The Ss were 14 female and 11 male graduate students in educational psychology.

Apparatus

The light source used in the TFT procedure was provided by a Grass Model PS-2 Photostimulator which generated a light source having approximately square wave characteristics with a flash duration of 10 milliseconds and intensity at the S's eye of approximately 90,000 candlepower or 1,113,000 lumens. Duration of interflash intervals could be varied from 15-150 milliseconds. The point source of light of 1/2 inch diameter was located in a soundproof cork insulated box (14 inch x 9 inch x 9 inch) and was diffused through a clear lucite aperture of 1/2 inch diameter and 1 inch in length. This flash source was located 18 inches from the S's eye at 5 degrees below retinal center, with visual angle being controlled through placement of S's chin in a Bausch and Lomb Model BA5372 chinrest.

Procedure

Prior to TFT measurement, S's eyes were dark adapted while wearing red lucite goggles in a semi-dark (15 watts illumination) 6 feet x 6 feet sound-treated room for 30 minutes followed by 10 minutes of adaptation in total darkness.

Viewing of the light source was binocular, with the S seated in a vertically adjustable chair with his chin in the chinrest. The S was asked to fixate upon the light aperture and respond by saying either "one" or "two" depending upon the number of light flashes he was able to see. He was informed that there would appear in the aperture either single or paired flashes of light at 10 to 15 second intervals. Practice trials were given in which a pair of flashes 150 milliseconds apart was presented as an example of what two flashes would look like, after which a pair of flashes 20 milliseconds apart was presented as an example of what a single flash would look like. Threshold was measured using a procedure similar to that of Farley (1969b) in which S is first presented with a long interflash interval and if he reports two flashes, he is then presented with a short interflash interval. If he then reports one flash, the procedure is repeated with decreasing range in 10 millisecond steps initially, until the point is reached at which occur two interflash intervals 2 milliseconds apart for which S reports two flashes for the longer and one for the shorter. These pairs of flashes are then twice repeated, and if the same responses as before are obtained,

then the last interflash interval at which S reported one flash is taken as his threshold.

RESULTS AND DISCUSSION

A scatterplot of the salivation (net) and TFT scores indicated a moderately strong linear relationship between the two variables with a computed regression equation of Y (TFT) on X (salivation) of $Y' = -27.79(X) + 89.74$. This distribution of scores is plotted in Figure 1, which contains the regression line.

Inspection of the plot reveals that the strength of the relationship decreases for the higher values of salivation and the lower values of TFT. Whether the relationship between these two variables ceases to be linear in this part of the range cannot be established on the basis of the present data. The explanation may lie in the fact that the distributions of both variables have a strong positive skew. This, combined with the present small sample size, results in insufficient cases in this part of the range to adequately determine the nature of the relationship. Generalization of these results should be generally restricted to low arousal Ss; that is, those with high TFT and low salivation responses. In other words, there may be discontinuities in the relationship at higher levels of arousal, although there are too few cases at the higher levels to justify a firm conclusion.

The product-moment correlation of salivation and TFT was -.57 ($p < .01$) which indicated that approximately 33% of the salivation

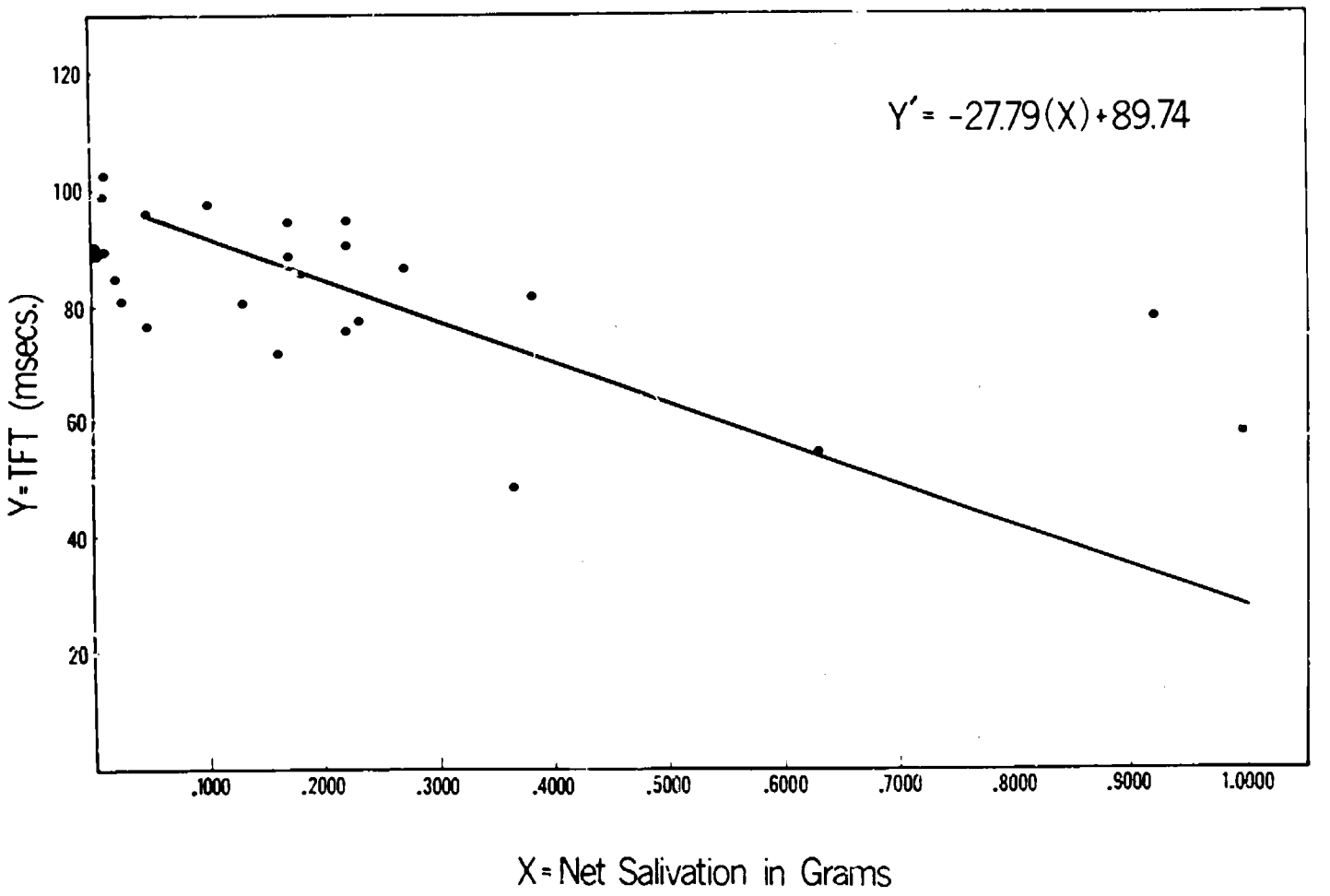

Figure 1. Regression of TFT on Net Salivation

variance was accountable in terms of the TFT measure. The comparable correlations of basal and gross salivation with TFT were -.19 (ns) and -.50 ($p < .02$) respectively.

It is clear from the present results that in the degree to which the TFT reflects cortical arousal, the salivary response as measured has been shown to be correlated with an index of arousal. The results can be inferred as supporting the construct validation of salivation as an indirect measure of arousal. This conclusion rests entirely on the validity of the TFT as an arousal indicant. The evidence cited earlier on this point is compelling. However, that the salivation and TFT correlation was only -.57 indicates that the IDs in net salivation are also a function of factors other than arousal, at least arousal differences as reflected in TFT scores. A further method of determining the validity of salivation as a measure of IDs in arousal would be the concurrent measurement of EEG during salivation sampling as presently taken, or the concurrent manipulation of arousal with EEG monitoring.

IV

GENERAL DISCUSSION

The results of the two foregoing experiments have provided tentative support for the use of salivation as a measure of IDs in arousal, with indications of reasonable reliability and construct validity. The construct validity of the measure has been further strengthened in the two reports by Farley and Gilbert (1968) and Osborne and Farley (1970) mentioned earlier, using IDs in salivation as a predictor of human memory. This work was based on a theory that arousal level interacts with the consolidation of memory, such that high arousal produces a more active consolidation process and thus better long-term memory, but will lead to depressed recall on an immediate test, due to the unavailability of the trace during the active consolidation process. Low arousal leads to the opposite effect; that is, good immediate memory but poor long-term memory, due to the relatively inactive consolidation process under lower arousal. In other words, the prediction was that high-arousal learning would lead to reminiscence from short- to long-term retention tests, or at least marked resistance to forgetting, relative to the consequences of low arousal, where more marked classical forgetting would be expected. In the two reports cited, these predictions were

confirmed both with Kindergartners and college students using a one-trial paired-associate task and immediate versus 24-hour retention measures, and extremes in salivation as measured in the present study as an index of IDs in arousal. These results would seem to further strengthen the construct validity of the salivary measure as an indicant of arousal. The particular value of the salivary measure in learning and memory research lies in its brevity and simplicity and its usefulness in studying the interaction of intrinsic arousal (putatively measured by salivation) and situationally induced arousal (e.g., as produced by white noise, induced muscular tension, etc.), although admittedly the act of measuring salivation has itself certain arousal-inducing properties. The usefulness of the measure in large-scale studies has been demonstrated by Farley and Eischens (1969) who administered the salivation measure to a large number of young children in a study of the retention of connected discourse in classroom settings. Using IDs in salivation as a measure of intrinsic arousal and inserted questions as a source of induced arousal, they studied the contribution of arousal to short- and long-term retention.

A further desirable characteristic of the salivation measure is that it allows for unidirectional quantification of a response to a standard stimulus rather than the more usual presence or absence of a response. Additional refinements and controls might include a parotid capsule device, fixed head rest, mouth clamps to immobilize

the mouth and greater control over Ss' diet and pretest activities. In addition, there is a need for parametric study of different time intervals between the measurement of basal and gross salivation as well as different amounts and qualities of the salivary response.

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